



The relationship of (perceived) epistemic cognition to interaction with resources on the internet



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ABSTRACT

Information seeking and processing are key literacy practices. However, they are activities that students, across a range of ages, struggle with. These information seeking processes can be viewed through the lens of epistemic cognition: beliefs regarding the source, justification, complexity, and certainty of knowledge. In the research reported in this article we build on established research in this area, which has typically used self-report psychometric and behavior data, and information seeking tasks involving closed-document sets. We take a novel approach in applying established self-report measures to a large-scale, naturalistic, study environment, pointing to the potential of analysis of dialogue, web-navigation – including sites visited – and other trace data, to support more traditional self-report mechanisms. Our analysis suggests that prior work demonstrating relationships between self-report indicators is not paralleled in investigation of the hypothesized relationships between self-report and trace-indicators. However, there are clear epistemic features of this trace data. The article thus demonstrates the potential of behavioral learning analytic data in understanding how epistemic cognition is brought to bear in rich information seeking and processing tasks.

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1. Introduction

The internet boosts our collective and individual capacity to store and seek information for a variety of purposes. Yet, “searching and processing information is a complex cognitive process” (Walraven, Brand-Gruwel, & Boshuizen, 2008, p. 623), and one that students across a range of ages find challenging (see, for example, Bartlett & Miller, 2011; Hargittai, Fullerton, Menchen-Trevino, & Thomas, 2010; Kammerer, Amann, & Gerjets, 2015; Livingstone, Bober, & Helsper, 2005; Van Strien, Brand-Gruwel, & Boshuizen, 2012; Walraven et al., 2008; Williams & Rowlands, 2007). Consider, for example, situations in which: a parent is attempting to

understand information around childhood vaccinations; a voter wants to investigate the plausibility of a politician's climate change claims; or someone seeking to lose weight wishes to investigate the merits of diet versus regular foodstuffs or supplements. In each case, the information seeker requires more than just the ability to read content; the information seeker must make decisions about where to look for information, which sources to select (and corroborate), and how to synthesize (sometimes competing) claims from across sources. These information skills are key literacy skills for 21st century multimedia environments (OECD, 2013; OECD & Statistics Canada, 2010), indeed “reading literacy is understanding, using, reflecting on and engaging with written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society.” (OECD, 2013, p. 9).

In this article, we argue that processes of information seeking and processing relate to the epistemic cognitions – beliefs about knowledge and knowing – which are brought to bear on the information found and their relevance to completion of a particular task (Bromme, Pieschl, & Stahl, 2009). Specifically we agree with

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Hoer, that, “exploring students’ thought processes during online searching allows examination of personal epistemology not as a decontextualized set of beliefs, but as an activated, situated aspect of cognition that influences the knowledge construction process” (Hofer, 2004, p. 43). Empirical evidence indicates that, in self-report and talk-aloud data in controlled experimental studies, there is indeed such a connection between epistemic beliefs evidence by psychometric assessment and information seeking. However, more naturalistic large-sample contexts – including the socially situated nature of information seeking - have not typically been studied, nor the digital trace data created in such information seeking. It is the aim of this paper to investigate these issues, to provide analysis of epistemic cognition in the context of a more socially oriented, naturalistic, study environment.

1.1. a. Background

A common class of research across the epistemic cognition literature has focused on its role in multiple document processing (see reviews by, Bråten, 2008; and, Ferguson, 2014). This sort of research is particularly interesting in the context of information seeking, given the need in such activities to deal with multiple websites (documents) and their potentially conflicting, and related, information. A typical pattern in this research involves gathering psychometric data on epistemic cognition, and then asking students to engage in some task – constructing an argument, or summarizing information – using a number of pre-selected documents, selected for their variability in terms of credibility and information.

Some of this research has further utilized think-aloud protocols to gather epistemic data, notably that of Mason, Boldrin and Ariasi (2011; 2010a, 2010b) who find that students do spontaneously reflect on epistemic concerns in information seeking while using a ‘dummy’ search interface (designed to return a pre-selected set of documents). Additional work in online information seeking contexts suggests that students with more “evaluative stances” on psychometric measures are more likely to meaningfully evaluate websites, with integration and critical evaluation of multiple online sources more likely of those with more sophisticated perspectives on the “multiplicity of knowledge” (Barzilai & Zohar, 2009, 2012). Further preliminary work suggests an association between “evaluativist” beliefs and comprehension of multiple conflicting online sources, but not multiple converging perspectives in online sources (Barzilai & Eshet-Alkalai, 2013). However, it should be noted that the use of think-aloud protocols may – as an artefact of the method – increase practices such as credibility judgements (Schraw & Impara, 2000; Schraw, 2000, pp. 297–321).

Navigation of rich multimedia environments introduces additional complexities to information seekers. However, such environments also increase the availability of data to study human interactions with them, in order to understand core literacy concerns such as how people select, evaluate, and integrate claims. A body of work on epistemic cognition has emerged investigating this issue, however, while some work has made use of think-aloud protocols, most research has used controlled document sets, and has not made use of digital trace methods to examine information seeking patterns. Three approaches have emerged in the extant literature thus far, involving investigation of:

1. student's assessments of the trustworthiness of documents known to the researchers
2. self-report psychometric instruments regarding internet specific epistemic cognition
3. student's self-reports of information seeking practices

1.2. Trustworthiness assessments in multiple document processing

Within the document processing literature, one research paradigm has been to ask students to assess the ‘trustworthiness’ of the resources they have encountered. That research has demonstrated that, more advanced students are – when they engage in evaluative behaviors over a set of provided documents – more likely to trust unbiased and less likely to trust biased sources (Anmarkrud, Bråten, & Strømsø, 2014). Furthermore, even while controlling for prior knowledge and text comprehensibility, students who believe in personal interpretation are less likely to trust documents, and those who believe claims should be evaluated are more likely to trust scientific documents than those relying on experience (Strømsø, Bråten, & Britt, 2011); indeed across students there is greater trust in textbooks than news sources, with a focus on content over date of publication in making judgements regarding trustworthiness (Bråten, Strømsø, & Salmerón, 2011).

In the two key studies of Anmarkrud et al. (2014) and Bråten, Braasch, Strømsø, and Ferguson (2014) students were given six texts to read (on the cancer-risks of mobile phones) with conflicting perspectives and varying source-feature trustworthiness, with the framing prompt to:

Imagine that a close friend has told you that she experiences discomfort when using her mobile phone. She has asked you for advice and you have searched the Internet for information about the topic. The search resulted in six results ... (Anmarkrud et al., 2014, p. 5; Bråten et al., 2014, p. 18).

The participants were instructed to read the six ‘search results’ over 40 min, in order to provide their friend with “well-grounded advice”. They were then given an essay prompt, to address in 20 min, without access to the source-documents:

You are now going to write a brief report where you judge the health risk of cell phone use. Base your report on the texts that you just read and try to express yourself clearly and elaborate the information—preferably in your own words. Justify your conclusions by referring to the sources you have been working with (Anmarkrud et al., 2014, p. 4; Bråten et al., 2014, p. 15, p. 15).

This follows earlier research (Anmarkrud et al., 2014; Bråten et al., 2014) in which students were asked to read multiple conflicting documents and, following writing a short report, rank those documents according to their trustworthiness. Following ranking, they were then asked to give reasons for their decision. In that earlier work, students were given only the title and metadata (e.g. author, publisher, date of publication) rather than the complete content of the document. As such, their trust assessments were based off recollection or features foregrounded in the metadata and title, rather than a holistic assessment of the original source. In addition, ranking forces ordinal judgements, and cannot represent interval-level distinctions. As such, a document set of three with two equally ‘low’ and one ‘high’ rated document would be ranked on a 1–3 scale, where – in contrast – a rating scheme (of 1–5) might permit a ranking of ‘1’ ‘1’ and ‘5’. There is thus scope for analysis of ratings of trustworthiness based on holistic features of source documents.

1.3. Internet specific epistemological Beliefs

One psychometric instrument of particular relevance to information seeking and epistemic-commitments is the ISEQ (Bråten, Strømsø, & Samuelstuen, 2005), which has been deployed in several similar tasks to the one described here (Kammerer, Bråten, Gerjets, & Strømsø, 2013; Kammerer et al., 2015; Strømsø & Bråten, 2010). The ISEQ is a 36-item instrument with a 4-factor conceptual

structure mirroring the broad model of epistemic-cognition described in Mason et al., (2010a): simplicity; certainty; justification; and source of knowledge. Empirical validation of its structure (Bråten et al., 2005) with 157 Norwegian political science undergraduates indicated a two factor structure, rather than the four factor structure initially conceptualized: a justification factor (α 0.70) with 4 items scores on which range from a perspective that internet-based knowledge claims can be accepted without critical evaluation to a perspective that they should be corroborated and critiqued; and a general internet epistemology factor (α 0.90) with 14 items scores on which range from a perspective that the internet can give true, specific facts, to a perspective that the internet is not a good source of true facts.

Subsequent work (Strømsø & Bråten, 2010) using this tool and self-report data has found that:

1. Students who believe internet information is a source of detailed factual information are less likely to report problems with information seeking on the internet, and
2. Students who thought that the wealth of information available on the internet was an advantage, were more likely to report seeking expert help in their information seeking.
3. Similarly, those considering internet information to be detailed and concrete engaged in more self-regulatory activities.
4. Those believing facts needed checking (and reasoning) were more likely to report engaging in self-regulatory strategies like planning.

Further experimental ISEQ work with 79 undergraduate students, used the context of a controlled information seeking task using pre-selected conflicting information (from the internet) regarding a medical issue (Kammerer et al., 2013). That research analyzed the ISEQ results in the context of log files, eye tracking, and verbal protocols finding that:

5. Students with beliefs in the internet as a source of reliable, accurate, and detailed facts were less likely to reflect on the credibility of sources and URLs while maintaining more certainty in their search-decisions.
6. Correspondingly, those who had doubts about the need to check sources were more likely to have a one-sided representation.

Both findings suggest a clear relationship between epistemic cognition and internet information, with the use of both self-report and trace data methods in the latter study of particular interest. Survey studies (Bråten & Strømsø, 2006; Bråten et al., 2005; Mokhtari, 2014) indicate relationships between aspects of epistemic cognition, and internet information seeking behaviors; however, while self-report measures give productive insight and useful indicators of variance (for example, in beliefs), beyond the typical limitations of self-survey instruments, they can be challenging to interpret in the context of behavioral processes or apply across disciplines and task types.

1.4. Information seeking credibility assessment behaviours

Much of the information seeking and epistemic cognition research has, drawing on models of literacy such as the OECD's and the work of Britt and Rouet (Rouet & Britt, 2011), developed a multiple document comprehension research paradigm. In these multiple document processing (MDP) tasks, participants are asked to process multiple documents, to find, evaluate, and integrate, information from across those documents. Indeed, Mason et al., (2011, 2010a, 2010b) adapted this approach, using a dummy search interface to display a set of pre-selected documents to

students in a 'search-like' interface. Therefore, there has been relatively little work on information seeking in more open contexts, such as the web.

In addition to the small body of work making claims relating epistemic cognition to observable behavioral differences, there is a body of research – typically not from educational contexts – which has explored approaches to track and highlight the salient features of web navigation with, for example, tools developed to support information seeking and review of information behaviors (Hwang, Tsai, Tsai, & Tseng, 2008; Lin & Tsai, 2007; Tseng, Hwang, Tsai, & Tsai, 2009), and analysis of information seeking behaviors such as use of the browser's 'back' button in the context of 'scientific epistemic beliefs' (Hsu, Tsai, Hou, & Tsai, 2013). In this latter study of a sample of 42 undergraduate and graduate students, participants were first asked to read two competing articles on a scientific dispute, and then asked to justify which they trusted more, and if their position changed (and why) during searching for justificatory material. The participant log data was recorded with a coding scheme of online behaviors giving a code to various acts. Students with higher self-report Scientific Epistemic Beliefs (SEB) were more likely to: show bi-directional sequences of 'query-results browsing'; and results browsing involving viewing more than one page of search engine results, than those with low SEBs. High SEB students were also more likely to use the 'back' button to browse earlier information. They thus conclude that high SEB students display more advanced search behaviors.

Drawing on the research outlined in this literature review, a set of metrics can be drawn from the (smaller number) of studies explicitly making use of trace data in their analysis. Across a broad set of studies (for example, Lin & Tsai, 2007; Salmerón & Kammerer, 2012; Shah & González-Ibáñez, 2011; Shah, Hendahewa, & González-Ibáñez, 2015) the viewing of pages has been highlighted, often along with some metric of 'page use' indicated by explicit marking actions by a user (for example, bookmarking) or implicit actions (for example, citing the page, copying text from the page). In addition, the number of search queries made (Shah & González-Ibáñez, 2011; Shah et al., 2015), the 'depth' of query probing (i.e. various measures around searchers going past the first few results into subsequent pages) (Hsu et al., 2013; Lin & Tsai, 2007; Salmerón & Kammerer, 2012; Shah & González-Ibáñez, 2011; Shah et al., 2015), the number of keywords (Lin & Tsai, 2007; Wu, Hwang, & Kuo, 2014) and number of keywords in relation to number of queries (Yue, Jiang, Han, & He, 2012) have been reported as recent analytic devices. Other metrics reported have included: time spent on pages or search engine results pages (Salmerón & Kammerer, 2012; Wu et al., 2014); sequence analysis (for example analysis of patterns of query->page, or page->page navigation) (Hsu et al., 2013); page revisiting (Lin & Tsai, 2007; Wu et al., 2014); and analysis of pages visited but not used (Wu et al., 2014). Building on some of these measures, a set of metrics has been composed (Wu et al., 2014) around the 'symmetry' of collaborative user activity, indicating whether one partner in a pair is contributing more to any particular metric than another – for example, whether one is adding more bookmarks than the other.

Across the information seeking and epistemic cognition literature, experimental paradigms tend to assign tasks and document sets, with more or less specificity around the purposes for which information is being sought. This distinction, though, is important, as producing a 'summary' (distilling claims from documents) versus an 'argument' (justifying stances on claims from documents) produces different kinds of behavior – including in mediating the kind of talk aloud or collaborative dialogue students engage in – as well as end product (Bråten & Strømsø, 2009; Cho, Lee, & Jonassen, 2011; Gil, Bråten, Vidal-Abarca, & Strømsø, 2010; Hagen, Braasch, & Bråten, 2012).

A body of work has emerged in the information science literature regarding *collaborative* information seeking (CIS) (see, for example, Hansen, Shah, & Klas, 2015; Shah, 2012). As Kuiper, Volman and Terwel (2009) conclude, "... the conditions for students working collaboratively [in information seeking] deserve attention. Our results confirm the importance of collaborative inquiry activities being more than just 'working together'" (Kuiper et al., 2009, p. 679); noting the importance of students communicating with each other to share their goals, improving motivation and common knowledge. Indeed, it has been noted that in educational contexts, information seeking often involves some form of collaboration and dialogue, and that this interaction is an important research site (Ellis et al., 2002; Foster, 2009). In parallel, in the education and learning literature such collaboration has been flagged as a possible means to improve self-regulation and overcome an 'inert knowledge problem' in which students fail to articulate what they know, to successfully solve search challenges (Lazonder, 2005). In that work, with 40 students ($M = 20$ years old), those collaborating were faster and (marginally) more evaluative than those searching individually. In work directly relating the collaborative interaction in information seeking and epistemic cognition, Knight and Mercer (2015, 2017) showed that, with a small sample of 11 year olds, clear epistemic markers could be identified in the dialogue of the small groups. Exploration of a collaborative information seeking context, then, yields three primary benefits: (1) it recognizes the oft collaborative nature of information seeking, particularly in classroom contexts; (2) well designed, it may hold pedagogic benefit to student learning and; (3) collaborative interaction provides a site for research, providing an alternative to talk aloud methods.

Thus, a collaborative information seeking task was designed, to elicit trace markers as described above. Following Wildemuth and Freund (2012) key lessons arising from a review of the design of search tasks:

1. Tasks should be focused on learning and investigation
2. Context and situation should be specified but the topic or request may introduce enough ambiguity and open-endedness to produce exploratory behaviors
3. Multiple facets should be included in the task and search topic
4. Possibility for eliciting dynamic and multi-stage search should be considered; in some cases tasks can be written to provoke this, but this will not always be the most appropriate approach
5. Data collection and evaluation should be aligned with the goals of the task

1.5. Research questions

Prior research has established the epistemic nature of information seeking contexts, indicating the potential of talk aloud and survey item self-report to probe these contexts. This work has demonstrated the epistemic nature of information seeking and processing, and the potential of psychometric and other self-report data in understanding this epistemic context. However, the three research approaches described in sections 1.1–1.3 above have not been well combined, relying on self-report data, and often focusing on controlled situations with pre-selected resources of clear credibility (i.e. the worst and best resource is apparent to expert readers). In particular, there is scope for further analysis including the use of trace data, and more naturalistic web search contexts. The research reported in this article is novel in using a psychometric instrument alongside evaluation of documents sourced through an information seeking task, and fine-grained learning analytic observations of those task behaviors. In so doing, the aim

was to bring together multiple lines of research, in order to investigate and compare their relationships, while also shifting investigations to more naturalistic, socially oriented, but large-scale, contexts. Thus, this research investigated:

1. To what extent is the ISEQ predictive of document trust ratings for materials found during information seeking?
2. To what extent is the ISEQ predictive of self-reported search expertise?
3. To what extent is the ISEQ predictive of observed trace markers of search expertise?

2. Methods

2.1. Design and context

The primary research described took place over the course of a week, involving 75 min sessions with groups of 25–35 undergraduate students. The study took place at the Maastricht University School of Business and Economics, during skills sessions for a first year Quantitative Economics class. This university school is highly selective, with a strong international representation in the student body (over two thirds of the cohort from an international background, mostly European), and English as the primary language of instruction. It also employs a student-centered learning approach called "problem-based learning" (PBL). As PBL involves small-group collaborative learning on open-ended problems, these students are familiar with the use of collaborative learning activities such as those used in this research. This method of curriculum design has demonstrated outcomes, with student's appreciating the style of learning, and gaining improved inter-personal skills for such tasks (H. G. Schmidt, Molen, Winkel, & Wijnen, 2009). A between-subjects design was used, with materials as described in the following sections.

2.2. Participants

Participants were students attending computer skills sessions, participating on an opt-in basis (with an alternative course-task provided for those who chose not to participate, $n = 16$). In total 1148 students participated in the study; this paper focuses on 308 students (125 female, 183 male, with an age of $M = 19.01$, $SD = 1.32$) who took part in the Collaborative Information Seeking condition reported in this paper, and excludes a number of students for whom there was data loss.¹

2.3. Ethics

The Open University Human Research Ethics Committee reviewed and approved the research described in this work. The British Psychological Society (2014) Code of Human Research Ethics, and British Educational Research Association (2011) Ethical Guidelines for Educational Research were followed.

Participants in this study were in a cohort of students who have, in advance, consented to use of their educational data, in an anonymous format, for educational and research purposes, a process described in Tempelaar et al. (2012, sec. 3.2–3.3); specifically consenting to analysis of self-report questionnaires or psychometric instruments and educational outcomes. In addition, participants were: informed in advance a week prior of the study; given a

¹ T-test comparison of means and chi-square test of independence across a number of demographic and survey items indicate no significant differences between the students analyzed in this paper and those for whom data is not reported.

briefing at the beginning of the study-session; and given both a paper description and full online consent form for further detail. Participants consented by ticking an on-screen box, logging into the system (using a login given to them) and submitting their unique student ID number. In doing so the participants consented to Maastricht University sharing data with the Open University team and the standard terms of use of Coagmento (<http://www.coagmento.org/terms.php>) including the collection of browser-data (this was verbally noted, separately included in the consent details, and a link to the Coagmento terms provided). All procedures and materials were negotiated with our collaborator and gatekeeper at Maastricht University. Participants could opt to take part in the study, or to complete a separate course-task; this is akin to the option for course-credit (although it should be noted that neither option provide *extra* course credits). The study took place in a Maastricht University lab setting using university PCs.

The task was framed with the research interest that: “the researchers are interested in developing tools to support students in finding and evaluating information together”. This claim is a true but partial disclosure given the research emphasis is on understanding differences in patterns of information seeking and evaluation, rather than in aspects of software design or human-computer-interaction. A full debrief, describing the study more completely, was given following completion of both parts of the study.

The study was specifically designed to be educationally beneficial to participants in its own right, in addition to analysis holding wider benefit to our understanding of epistemic-cognition and source-evaluation. While the main topics were not directly relevant to the students the skills used in such tasks – of seeking, evaluating, and writing up information in small groups – are important transferable skills, and there are reasons to believe that collaborative information seeking holds educational value.

2.4. Materials

2.4.1. Trustworthiness instruments

Based on the literature reported in section 1.1 above, following the main task (during the lab-session) participants were asked to rate the trustworthiness of the most, least, and average website they visited on a 1–10 scale. Specifically, students were asked to give three ratings (on a 1–10 scale), indicating trustworthiness scores for the: most, least, and average trustworthiness of the resources they had found. In addition they were asked to give a URL for the most and least trustworthy resource, and to give general comments on the type of resources found as follows:

- Please rate how trustworthy the information you found in this task was on average (10 = The sources were high quality, and the information was very credible, 1 = The sources were low quality and the information lacked credibility)
- Please give an estimate rating for the *least* trustworthy page you found where 1 is ‘not at all trustworthy’ and 10 is ‘very trustworthy’ (if you can remember it, please post the URL here)
- Please give an estimate rating for the *most* trustworthy page you found where 1 is ‘not at all trustworthy’ and 10 is ‘very trustworthy’ (if you can remember it, please post the URL here)
- Please give any other feedback or commentary on examples of types or sources of documents you found, and how trustworthy you found them in the space provided.

2.4.2. ISEQ instrument

Based on the research reported in section 1.2 above, establishing the reliability of the psychometric tool, participants completed a 7

point scale version of the English ISEQ (Bråten & Weinstein, 2004). This was completed in advance of the lab-session using the same system as the students use to complete similar survey items as part of their course (as described above).

2.4.3. Self-report information seeking and information seeking task

Finally, based on the research reported in section 1.3 above, participants were asked a number of survey questions, including to give a self-report of their search expertise, responding on a five point anchored scale to the question “How would you describe your search experience?” from “very inexperienced”, to “very experienced”. Alongside the self-report measures of search, a subset of trace indicators was obtained as indicated in Table 1. These indicators were selected based on the established literature (see section 1.3) into behaviors surrounding credibility assessment. They provide an initial learning analytic approach to the investigation of the potential of trace data in investigating epistemic cognition in the rich contexts described in this article.

In this research, a topic was selected involving searching for information on the internet. Following the work described above, a topic with conflicting perspectives and a variety of source-qualities was sought to foreground participant’s commitments to varying source-content qualities. A number of sources giving ‘scientific controversies’ were explored to select an appropriate topic, and a topic was identified which:

1. provide a focused topical research area which could be studied in isolation, within a 1 h session;
2. was not a topic that was high profile or/and a large scale controversy (such as climate change, or genetically modified crops, both of which receive a lot of press coverage);
3. had a variety of source-types and qualities referring to it, from varying perspectives.

A theme was identified and explored by the first author to ensure it was appropriate for use in the research. The topic of ‘red yeast rice’ was selected based on its presence under the sub-category of ‘Medical controversies’ in Wikipedia’s Scientific controversies category (https://en.wikipedia.org/wiki/Category:Medical_controversies) in Wikipedia’s Scientific controversies category (https://en.wikipedia.org/wiki/Category:Scientific_controversies). This case was identified as interesting because:

1. Using search engines to seek information on health issues, such as use of food supplements, is a common issue (See, for example: use of Wikipedia, Heilman et al., 2011; survey data, Horgan & Sweeney, 2012; and log data, C. W. Schmidt, 2012) and requires evaluation of claims from across various types of sources;
2. The Wikipedia article on ‘red yeast rice’ is not particularly high quality (it is rated ‘b-class’ in the ‘alternative medicine WikiProject’ quality scale). *Monascus purpureus* (its scientific name) does not receive a rating on any relevant scientific or medical WikiProject scales (but is a stub article, i.e. it is very short);
3. Search engine results pages show varying results for queries on ‘red yeast rice’ and *monascus purpureus*;
4. The controversy is largely around restrictions and side effects (i.e. it is uncontroversial that the substance has a medical effect, although risks and scope of those effects are disputed).

Further research indicated that the substance had received some public attention including from regulatory agencies in France and America (ANSES, 2014; FDA, 2007) based on concerns regarding the concentration of the active ingredient (Gordon, 2010), and concerns reported in the press regarding its

Table 1
Trace indicators.

Variable Name	Description
Ug	number of unique pages visited
Urg	number of unique pages used, operationalized as those pages referred to in the chat, etherpad, or from which data was copied or snipped
N query	number of queries
Query vocabulary richness	Number of unique terms in all queries/number of queries
Query depth	search engine results pages viewed past the 1st page
ChatTaskTotal	number of chat messages sent

contamination with citrinin (Harding, 2008). Alongside this, there were also reports in the popular press (Macrae, 2008) citing research (Lu et al., 2008) on its positive impact, and medical advisory sites providing a science-literacy perspective on this (NHS Choices, 2008). In addition, red yeast rice is widely (correctly) reported as containing the same active ingredient as 'statin' drugs, which have various known side-effects, and have had somewhat controversial coverage in the press in their own right (See, for example, Boseley, 2014; Gallagher, 2014; Ridker & Cook, 2013). Three key themes were identified in this search, first that red yeast rice should be treated as a statin, second that the concentration levels of the active ingredient in red yeast rice vary, and third that some samples of consumer purchased red yeast rice have been contaminated with citrinin. Thus, the potential set of documents participants might encounter in researching the assigned topic offers conflicting information from sources of varying quality, with a range of sub-topics present.

The task was presented using a website which required login provided to students at the start of their session. The procedure is described further below, here we note that the main task involved a set of instructions (see Appendix 1), a space to write their answer, on a separate webpage (using the collaborative text editor, etherpad), and collaboration tools provided via Coagmento. These Coagmento features comprised a chat tool, and an awareness feature that foregrounded the searches being made by one's partner; additionally, the tool logged all page views, and 'copy' actions made by participants.

The task prompt was written to foreground student's understanding of knowledge claims, and support for those claims. For example whether they corroborated, emphasized source features and source-credibility, or evaluated source-content and methods used in sources. Thus, students were not asked to "refer to the sources you have been working with", but instead asked to work together to "Produce a summary of the best supported claims you find and explain why you think they are." The aim of these instructions is to guide the participants in their task, encouraging them to explain their decision processes as they go, while not directing them in particular to either sourcing via corroboration or authority (and explanations thereof).

2.5. Procedure

Prior to the lab session the student cohort was informed of the possibility of taking part in the research study, and briefly what it would involve. They also completed the ISEQ (along with various other survey items), as part of their usual course. Participants worked on separate PCs in a computer lab with Firefox (Mozilla, 2014) installed along with the Coagmento browser add-on (Shah, 2014), designed to facilitate collaborative information seeking, and provide researchers with trace-data logs. Participants worked mostly in pairs (although due to uneven numbers and late arrivals a small number worked in trios or individually). Before each particular study session, PCs were logged on to a generic logon, with

Firefox open, and on the 'login' page for the study. The browser cache was cleared and any extra windows or programs open closed. Each PC also had a paper copy of core instructions, and the times for each task were written on a board at the front of the room for researcher and participant reference. Those times are given in Table 2.

Participants were instructed to login using details provided to them, complete a consent form, and a short warmup task (involving collaborative information seeking) to familiarize themselves with the features in the Coagmento system. After 10 min on this warmup task, participants were encouraged to begin the main task; the researcher and lab assistant ensured all participants started the main task at approximately the same time, and participants spent approximately 45 min on this task, receiving a 10 min warning before the end of that slot. The session ended with the short (under 10 min) exit questionnaire. At the end of each session the procedure described above was followed to setup for the following group.

3. Results

We first discuss the factor structure of the instrument, before giving descriptive statistics regarding the target group's ISEQ scores. Afterwards, we discuss the 'trustworthiness' assessments, which were collected both as an explicit epistemic trace-marker to compare the ISEQ scores against (following previous research).

3.1. Internet specific epistemological questionnaire (ISEQ)

The 36 item ISEQ was completed by 1003 students (all of whom had consented as participants in the study). Exploratory factor analysis was conducted to investigate the underlying factor structure. We follow Bråten, Strømsø, and Samuelstuen's (2005) ISEQ procedure, and Costello and Osborne's (2005) general factor analysis guidance, in selecting oblimin rotation throughout (because we expect factors to be correlated), and a 'maximum likelihood' factor selection method. Factor structures were iterated four times until a satisfactory structure was discovered.

On no iteration was a third (or more) factor identified satisfactorily with such solutions resulting in cross-loadings, low loadings, or single-item factors; a fourth iteration did not suggest an improved factor structure. Nor was the factor structure improved by single factor models. Note that the factor structure is almost identical to that of Bråten et al. (2005), giving an identical

Table 2
Lab-session timings.

Time	Activity
0–5	Introduction to session from lab-assistants and primary researcher
5–10	Login, consent, basic familiarization with Coagmento
10–20	Warmup task (3 min warning given at end)
20–65	Main task (10 min warning given at end)
65–75	Post-task survey

Table 3
Descriptive statistics for CIS trustworthiness ratings.

	M	SD
Least trustworthy rating	4.67	1.75
Average trustworthiness rating	7.20	1.43
Most trustworthy rating	8.87	1.01

'Justification' factor, and 2 varying items: items 9 and 32, written to probe the simplicity and source of knowledge respectively, were removed while items 13 and 7 – written to probe the same respective constructs – were added.

The final two-factor solution gives 18 items with high loadings (>0.4) and low overlap (<0.3)². The two factors had eigenvalues of 6.12 and 2.65 respectively and explained 24.8% and 9.7 of the sample variation respectively, or 34.4% in total. This compares to the 6.60 and 2.28 respective eigenvalues and 47% sample variance explained in Bråten et al. (2005). Cronbach's alpha may be compared favourably to Bråten, Strømsø, and Samuelstuen's (2005) finding of 0.90 and 0.70 respectively. Note that for both factors, higher scores should be interpreted as indicating more naïve perspectives.

A confirmatory factor analysis was conducted on this model. Fit indices for this two-factor model indicate a reasonable fit between the model and the data, goodness of fit index = 0.93, adjusted goodness of fit index = 0.90, comparative fit index = 0.89, root-mean-square error of approximation (RMSEA) = 0.063, with 90% confidence limits of 0.058–0.068. This compares to respective fit indexes of 0.86, 0.82, 0.95 and RMSEA of 0.067 (with confidence limits of 0.05–0.08) reported by Bråten et al. (2005). Analysis indicates that on the general factor the target group had a mean score of 4.11 (SD = 0.80), and on the justification factor a mean of 2.85 (SD = 0.80).

3.2. RQ1: relationships between ISEQ and trust ratings

Trustworthiness assessments were collected for the documents encountered based on an average-highest-lowest 1–10 rating for resources visited. All of the 308 participants completed the trustworthiness assessment survey – giving a 1–10 'trust' rating to the most, least and average website trustworthiness observed.

Analysis of responses to the CIS trustworthiness survey indicated that some participants had very low standard deviations across their ratings, implying a universal or near universal rating strategy. Therefore any responses with a range of 0 ($n = 10$) or: giving a higher rating to the 'least trustworthy' or 'average' resource than 'most trustworthy' ($n = 9$, $n = 11$), or to the 'least trustworthy' than the 'average' ($n = 20$); was excluded ($n = 29$ cases, giving $n = 39$ excluded overall), leaving 269 valid cases remaining,³ summarized in Table 3⁴.

Multiple regression analyses indicate small significant effects of

² Note, Bråten et al. (2005) remove items with >0.2 overlap.

³ Note, equal ratings for two out of three responses did not result in listwise exclusion.

⁴ T-test analysis of ISEQ scores between those excluded and included in the trustworthiness analysis indicates significant differences between the groups on the justification ($t(51.16) = 2.59$, $p = 0.01$) but not the general ($t(49.18) = 1.55$, $p = 0.1$) factors. The excluded group had a non-significant lower ISEQ general score ($M = 3.92$, $SD = 0.81$, $n = 39$) than the analysis group ($M = 4.14$, $SD = 0.79$, $n = 267$), with a small effect size $r = 0.14$. Conversely, the excluded group had a significantly higher ISEQ justification score ($M = 3.14$, $SD = 0.76$, $n = 39$) than the analysis group ($M = 2.80$, $SD = 0.80$, $n = 267$) representing a small effect size $r = 0.21$, indicating that the excluded group had scores suggestive of less sophisticated perspectives on the justification of knowledge.

ISEQ scores related to trustworthiness ratings. Multiple linear regression predicting the least trustworthiness score based on the ISEQ general and justification factors indicated a significant effect ($F(264) = 7.15$, $p < 0.001$, $\text{adj } R^2 = 0.044$), the ISEQ General score was significant ($\beta = 0.204$, $p < 0.001$), as was the ISEQ Justification score ($\beta = 0.152$, $p = 0.014$). Thus, indicating that ISEQ scores had a small predictive effect for least trustworthiness scores such that higher scores (on both factors) were related to increases in trustworthiness assessments – that is, those with less sophisticated epistemic perspectives rated the least trustworthy pages they encountered more highly than those with more sophisticated (lower ISEQ score) epistemic perspectives. In contrast, in the model for ratings of the most trustworthy resource (which is marginal at $p = 0.065$; $F(264) = 2.76$, $p = 0.065$, $\text{adj } R^2 = 0.013$), there was a small effect for the ISEQ general factor ($\beta = -0.121$, $p < 0.053^*$) and a marginal small effect for the ISEQ justification factor ($\beta = -1.71$, $p = 0.089^*$) such that higher scores on these factors were associated with lower ratings of the most trustworthy resource encountered. That is, participants with less sophisticated perspectives had lower ratings of the most trustworthy resources they encountered. The model for average trustworthiness is not significant at the 0.05 level ($F(264) = 1.30$, $p = 0.274$, $\text{adj } R^2 = 0.002$).

3.3. RQ2: relationships between ISEQ and self report search

Pearson's test of correlation on the paired ISEQ scores (i.e., taking the averages of each pair) indicated a relationship between the ISEQ general scores and search experience $r(150) = 0.197$, $p = 0.0145$; and a negative correlation between the justification factor and search experience $r(150) = -0.304$, $p < 0.000$, indicating an association between more sophisticated views on the justification of knowledge (lower scores) and self-reported search experience. This is paralleled in the individual data, with a Pearson's test of correlation indicating a small positive correlation between the ISEQ general score and search experience $r(304) = 0.204$, $p = 0.000$; which had a small negative correlation with the ISEQ justification score $r(304) = -0.182$, $p = 0.001$. This indicated a small relationship such that, as scores indicative of less sophisticated perspectives on the ISEQ justification factor increase (higher scores), search experience is decreased. The small positive relationship of ISEQ general scores to search experience is not aligned with expectation and may indicate that those with higher ISEQ general scores over-estimate their search experience. Multiple linear regression predicting search experience based on the ISEQ general and justification factors indicated a significant, but small, effect ($F(303) = 9.909$, $p < 0.0001^{***}$, $\text{adj } R^2 = 0.055$), the ISEQ General score was significant ($\beta = 0.172$, $p = 0.003^{**}$), as was the ISEQ Justification score ($\beta = -0.144$, $p = 0.01^*$).

3.4. RQ3: relationships between ISEQ and search-based traces

In addition to numeric self-report measures, finer grained learning analytic data was obtained from trace and self-reports of websites trusted. In this section, relationships between individual ISEQ scores and trace data are first reported, with paired data obtained by averaging ISEQ scores (giving a mean of 4.11 (SD = 0.58) on the General factor and 2.84 (SD = 0.57) on the Justification factor), and aggregating trace incidence across pairs. In addition, data around specific URLs visited and mentioned in the optional 'trustworthiness' questions is discussed.

3.4.1. Page visiting and use

Analysis of the log files was conducted to investigate the most visited, and most used, pages. Table 4 indicated the 20 most visited websites, also giving their rank in terms of usage. A trend for some

Table 4
Illustrative examples of pages used and visited.

rank	url	project count	% visited	% used	used rank	Website type
1	http://www.medicinenet.com/red_yeast_rice_and_cholesterol/article.htm	138	89.61	62.99	1	Lay health advice
2	http://www.webmd.com/cholesterol-management/red-yeast-rice	99	64.29	43.51	4	
3	http://umm.edu/health/medical/altmed/supplement/red-yeast-rice	90	58.44	56.49	2	
4	http://www.webmd.com/vitamins-supplements/ingredientmono-925-red%20yeast%20rice%20(red%20yeast.aspx?activeingredientid=925&activeingredientname=red%20yeast%20rice%20(red%20yeast	85	55.19	33.12	6	
5	http://articles.mercola.com/sites/articles/archive/2009/09/10/why-you-should-avoid-red-rice-yeast.aspx	79	51.30	29.22	8	Alternative medicine
6	http://en.wikipedia.org/wiki/Red_yeast_rice	79	51.30	22.08	12	Encyclopedia
7	http://www.medicinenet.com/red_yeast_rice_and_cholesterol/page4.htm	64	41.56	43.51 ^a	3	Lay health advice
8	http://nccam.nih.gov/health/redyeastrice	63	40.91	36.36	5	Alternative medicine
9	http://www.mayoclinic.org/drugs-supplements/red-yeast-rice/safety/hrb-20059910	59	38.31	24.03	10	Lay health advice
10	http://www.emedicinehealth.com/drug-red_yeast_rice/article_em.htm	57	37.01	18.83	13	advice
11	http://www.medicinenet.com/red_yeast_rice_and_cholesterol/page4.htm#how_safe_are_red_yeast_rice_products	57	37.01	25.97	9	
12	http://www.reuters.com/article/2008/07/09/us-contamination-common-idUSCOL97022820080709	54	35.06	31.17	7	News
13	http://www.drugs.com/mtm/red-yeast-rice.html	46	29.87	16.88	14	Lay health advice
14	http://altmedicine.about.com/od/herbsupplementguide/a/redyeastside.htm	41	26.62	16.23	15	Alternative medicine
15	http://www.medicinenet.com/red_yeast_rice_and_cholesterol/page2.htm	39	25.32	3.90	36	Lay health advice
16	http://www.nlm.nih.gov/medlineplus/druginfo/natural/925.html	35	22.73	23.38 ^a	11	Government advice
17	http://www.medicinenet.com/red_yeast_rice_and_cholesterol/article.htm#what_is_red_yeast_rice	33	21.43	11.69	17	Lay health advice
18	http://www.webmd.boots.com/cholesterol-management/guide/red-yeast-rice	31	20.13	11.69	18	advice
19	http://www.medicinenet.com/red_yeast_rice_and_cholesterol/page5.htm	30	19.48	6.49	25	
20	http://www.nutraingredients-usa.com/Suppliers2/Red-rice-yeast-supplements-raise-contamination-issues	29	18.83	11.04	19	Nutrition news

^a Note, the higher level of 'use' than 'viewing' may be as a result of strings matching in the use case without having been viewed (for example, by manually typing 'page4' on the end of a url that has not, in fact been visited). This discrepancy may also be a result of errors in the log data. The 'website type' column provides the researcher's assessment of the kind of information and authorship of each given resource.

pages indicated a discord between visiting and use. In some (for example, Wikipedia - rank 6 and used 12th) the trend indicates the page was under-used, perhaps indicating distrust or that the information was also found elsewhere; with others (for example, Reuters – rank 12 and used 7th) the reverse was true. Participants tended to view and use lay health advice pages, with very little viewing or uses of scholarly sources (for example, in total, 13 participants visited Google Scholar). Thus, analysis of the trace data indicates clear epistemic markers in the page navigation data.

3.4.2. From self-report to trace

Analysis of search logs – indicated in Table 5 – indicated a large range in the number of unique pages visited (range of 68), with a surprisingly large range in the number of pages used (with a range of 18 pages, and some groups mentioning only a single website in their chat, final product, or copy-actions). Similarly, we observed a large range (range of 99) in the number of messages sent. Smaller ranges were apparent in queries, although 'query depth' indicated that some groups browsed to the 6th page of search engine results pages. On further analysis (not illustrated here), most participants

Table 5
Summary of group data.

	n	mean	sd	min	max	kurtosis
Unique pages viewed	149	32.23	11.79	11.0	79.0	1.491
Unique pages used	149	6.19	2.78	1.0	19.0	2.253
Unique queries	149	12.12	5.33	2.0	27.0	-0.091
Query depth	149	0.21	0.81	0.0	5.0	21.326
Messages exchanged	149	34.42	18.94	2.0	101.0	1.566
ISEQGen	149	4.11	0.58	2.5	5.7	0.202
ISEQJust	149	2.84	0.57	1.5	4.8	0.272

(n = 135) did not pass the first page of results, meaning even a binary comparison ('deep query' groups, versus 'first page' groups) was not possible.

Theoretically, the hypothesis is that groups with more sophisticated perspectives should view more pages (to corroborate sources, and explore the range of information), and use a select few (to draw from the highest quality sources). As noted above, we might expect that more sophisticated groups would engage in more search, using a richer set of key terms, and browsing beyond the first page of search results. To negotiate navigation and evaluation, we might hypothesize that participants with more sophisticated perspectives would engage in more chat, generally sending more messages. Simple correlation analysis (Table 6) indicated no relationships between the ISEQ and the other scores.

4. Discussion

4.1. Research question 1: relationships between ISEQ and trust ratings

Factor analysis of the ISEQ indicated that the two factor structure previously reported – a justification factor, and a general factor – is supported by the data providing support from a large sample (n = 1003) for earlier research (Bråten et al., 2005) indicating that the conceptual model of factors regarding the source, justification, simplicity, and certainty of knowledge, is not supported by the empirical data. This replication with a larger sample and underlying two factor structure, indicates an empirical model which differs from the underlying conceptual model, suggesting need for new empirical and conceptual work in developing psychometrics for internet based epistemic cognition, including behavioral analysis.

Analysis of trustworthiness ratings indicated that most

Table 6
Correlation of trace and survey data.

	Unique Pages Viewed	Unique Pages Used	Unique queries	Messages exchanged	Query Vocabulary Richness	ISEQJust	ISEQGen	Search Experience
Unique Pages Viewed		0.45***	0.48***	−0.05	−0.18**	0.01	−0.01	0.08
Unique Pages Used			0.16*	−0.04	−0.10*	−0.01	0.00	0.03
Unique queries				0.02	−0.14*	0.03	−0.02	−0.03
Messages exchanged					0.03	−0.05	−0.01	0.03
Query Vocabulary Richness						0.09	−0.02	0.03
ISEQJust							0.22***	−0.19**
ISEQGen								0.22***
Search Experience								

<0.001 = ***; <0.01 = **; <0.05 = *; <0.1 = ^.

participants distinguished between the relative trustworthiness of the resources. The ISEQ general score had a small positive correlation to reports of ‘least trustworthiness’ and negative to reports of ‘most trustworthiness’ indicating that those with higher ISEQ scores (indicating lower epistemic-sophistication) rated the least trustworthy resources higher, and the most trustworthy resources lower.

These findings indicate that scores on a self-report psychometric instrument (the ISEQ) can be predictive of the ways in which participants assess the trustworthiness of resources they encounter in a relatively uncontrolled, collaborative, naturalistic web-based task. Nonetheless, the explained variance (1–4%) is relatively small, indicating the importance of other variables.

This finding provides novel large-scale regression-based support for the previous research finding that those with less sophisticated views may not rate high quality resources as well as those with more sophisticated views, as Strømsø, Bråten, and Britt (Strømsø et al., 2011, p. 17) report “readers who believe that knowledge claims should be critically evaluated through logic and rules rated the science text as more trustworthy These effects hold true while controlling for readers’ prior knowledge and text comprehensibility”. This effect may be because students with less sophisticated evaluative capabilities cannot appropriately evaluate, and thus distrust inappropriately – an interpretation supported by Livingstone et al. (2005) survey research – as such we would expect to see that higher ISEQ scores (less sophistication) are associated with lower trust in the most trustworthy material encountered (as is found).

While the observed relationship reported here is small, this finding in a large scale, collaborative, less-controlled environment supports the earlier self-report finding of Strømsø et al. (2011) and Livingstone et al. (2005). The finding also indicates that students with higher ISEQ scores rated the poorest resource they encountered higher in trustworthiness, indicating a poorer ability to discriminate appropriately between the trustworthiness of high and poor quality resources. These relationships are identified on an individual level (i.e. using data from individual participants), although the tasks were collaborative in nature. That these relationships are sustained in individual contexts despite the activity and reading processes being collaborative is a novel finding, and one which future analysis should explore. This finding highlights an important strength of the ISEQ in providing predictive potential for the ways in which participants in fact engage in trustworthiness assessment of resources. This suggests that further work could explore the ways in which psychometric properties of beliefs in pairs might differ from those in individuals.

4.2. Research question 2: relationships between ISEQ and self report search

The small correlations between the ISEQ factors and self report

search experience are of interest, and suggest that for the justification factor higher search experience was associated with lower ISEQ score (and vice-versa), and the converse for the general factor particularly given the absence of other correlations (which might imply, for example, a participant level response bias towards high/low scoring across self-report items). This suggests a relationship between justification sophistication and search capability, and that those with less sophisticated perspectives on the general factor perhaps overrate their own search capability. Given higher scores in both ISEQ factors indicate less sophisticated epistemic perspectives this effect on self-report of search experience may deserve further investigation.

Earlier research (Bråten et al., 2005) indicating a relationship between ISEQ scores and self-report internet-learning behaviors is supported by the small negative correlation between the ISEQ justification factor and self-report search experience for both the CIS and MDP task indicating an association between more sophisticated views on the justification of knowledge (lower scores) and self-reported search experience. Again, although the effects reported are small, the replication of this finding in a naturalistic, large scale, collaborative task context is important.

4.3. Research question 3: relationships between ISEQ and search-based traces

While analysis of self-report data (the ISEQ, self-report search expertise, and trustworthiness assessments) replicates prior small relationships, corresponding analysis of relationships with trace indicators does not yield significant results. Hypothesized relationships are not supported by correlational analysis between self-report data and particular information seeking indicators identified in page navigation, search engine use, and collaborative dialogue. This suggests that although correlates can be identified in self report data, these do not hold external validity in trace data obtained through naturalistic search tasks.

Despite this, there are clear sites for epistemic cognition observed within the trace data, in the navigation and selection of resources. Indicative analysis is given suggesting implicit trust assessments in the use of domains, alongside the explicit trustworthiness assessments made. This suggests both the importance of validation against external trace indicators, and the potential of those trace indicators for insight into epistemic cognition.

A limited set of trace indicators, adopted from prior research, are reported in this paper. Alternative and further composite indicators can be conceptualized that may be related to self-report measures (those established measures described in this article, or others). In addition, the article reports only from a single study-context, with a pedagogically motivated task design, and thus exploration of alternative tasks, and less-directed tasks, are warranted. Finally, the approach taken in this article – motivated by pedagogic and methodological interest – to focus on collaborative information

seeking creates a rich, but complex, context of study. However, the paper points to the potential of designing pedagogically motivated tasks to foreground sites of epistemic cognition. Epistemic cognition is an important feature in relation to advanced literacies. Thus, continued work to relate student credibility assessment, dialogue, search-based patterns, and other features in information seeking tasks that are specifically related to pedagogically meaningful contexts is important.

4.4. General discussion, limitations, and further research

Analysis indicates that a number of prior findings regarding self-report responses (the ISEQ, search-experience, and trustworthiness ratings) can be replicated in this large-scale study that incorporates authentic, collaborative, search tasks. As such there may be robust relationships between self-report features of relevance to search and epistemic cognition. However, these relationships appear to be small in nature, and not to relate well to a set of core search-based indicators. As noted in the introduction, prior work has not integrated the set of approaches described in this paper; this finding based on that integration is a core contribution of the paper. Despite this finding, there are clear epistemic markers in the search data in terms of the websites visited and used, the nature of the chat data, and so on. Thus, while the study builds on prior literature, it raises some important concerns for further research that moves beyond reliance on self-report data to analysis of behavioral indicators. Such analysis might consider search and navigational behaviors of students, their evaluative behaviors, and the dialogue that they engage in while searching for information, as well as analysis of artefacts developed from the information seeking and processing.

Across the findings reported here there are some clear limitations to validity and generalizability. Participants in this study were selected by convenience-sampling and self-selection via an opt-in design, based on their membership of an undergraduate class, receiving a dispensation on an alternative-course task for their participation. As described in the methods section, the participants are enrolled at a competitive-entry university, which has adopted a particular pedagogic approach (problem based learning). These factors mean that the specific results of this study may not be generalizable to other contexts. However, it is important to note that a core claim of the paper is that differences between participants can be identified in self-report and trace data, a claim supported by analysis; further research should probe this issue in other populations.

Similarly, a key feature of the research design in this study was the development of a pedagogical grounded information seeking task, involving collaborative information seeking on the internet. At a basic level, the information students might encounter regarding a particular topic is likely to change to a greater or lesser degree over potentially short periods of time. Moreover, the particular topic and task intent were selected for the purposes of eliciting the kinds of differences observed in our analysis. Indeed, a particular tool (Coagmento) was selected both to support the particular task design, and to provide the researchers with data regarding the behaviors that students engaged in. Further research is needed to understand the epistemic behavior of students engaged with related task designs, and with alternative tools including those that students might use in day-to-day internet browsing.

5. Conclusion

The internet is an important, but complex, learning resource. Extant epistemic cognition research has tended towards controlled document sets, with mock-up search features, in individual

information seeking contexts. The research described in this paper has adopted a more naturalistic approach, demonstrating a replication of prior small-relationships between self-report measures. However, the research described in this paper foregrounds a rich set of trace data, and hypothesized relationships between self-report indicators and trace-indicators are not evidenced. This suggests that although established self-report measures may provide reliable, and internally-valid indicators, other factors play a key role in information seeking, and self-report measures may lack external validity. Despite this, some possible sites of epistemic cognition are identified in the products of information seeking activities. Given the availability of information seeking trace through tools such as Coagmento, further exploration of learning analytic data should be conducted as described above. Further investigation is required to understand how epistemic cognitions are brought to bear in information seeking tasks. The novel approach taken in the paper points to the potential of analysis of dialogue, web-navigation – including sites visited – and other trace data, to support more traditional self-report mechanisms.

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Appendix 1

The text below thus gives the full task instructions used:

Your task is to act as an advisor to an official within the science ministry. You are advising an official on the issues below. The official is not an expert in the area, but you can assume they are a generally informed reader. They are interested in the best supported claims in the documents. Produce a summary of the best supported claims you find and explain why you think they are. Note you are not being asked to “create your own argument” or “summarise everything you find” but rather, make a judgement about which claims have the strongest support.

You and your partner should work together to find relevant materials on the internet.

You should:

- **Read the questions/topic** areas provided, these will require you to find information and arguments to present the best supported claims, you should decide with your partner which are best as you read.
- **Group information together** by using headings in the Editor
- You should work with your partner to explain why the claims you've found are the best available
- You should spend about 45 min on this task

References

- Anmarkrud, Ø., Bråten, I., & Strømso, H. I. (2014). Multiple-documents literacy: Strategic processing, source awareness, and argumentation when reading multiple conflicting documents. *Learning and Individual Differences*, 30, 64–76. <http://dx.doi.org/10.1016/j.lindif.2013.01.007>.
- ANSES. (2014). *Opinion of the French agency for food, environmental and occupational health and safety: On the risks associated with the presence of “red yeast rice” in food supplements (No. Request No 2012-SA-0228)*. ANSES. Retrieved from <https://www.anses.fr/fr/documents/NUT2012sa0228EN.pdf>.
- Bartlett, J., & Miller, C. (2011). *Truth, lies and the internet a report into young people's digital fluency*. Demos. Retrieved from http://demos.co.uk/files/Truth_-_web.

- pdf?1317312220.
- Barzilai, S., & Eshet-Alkalai, Y. (2013). The role of epistemic thinking in comprehension of multiple online source perspectives. In Y. Eshet-Alkalai, A. Caspi, S. Eden, N. Geri, Y. Kalman, & Y. Yair (Eds.), *Proceedings of the Chais conference on instructional technologies research 2013: Learning in the technological era*. Raanana: The Open University of Israel. Retrieved from http://innovation.openu.ac.il/chais2013/download/a1_1.pdf.
- Barzilai, S., & Zohar, A. (2009). The role of epistemic thinking in online learning. In *Proceedings of the Chais conference on instructional technologies research 2009: Learning in the technological era*. Raanana: The Open University of Israel. Retrieved from http://telem-pub.openu.ac.il/users/chais/2009/morning/1_2.pdf.
- Barzilai, S., & Zohar, A. (2012). Epistemic thinking in Action: Evaluating and integrating online sources. *Cognition and Instruction*, 30(1), 39–85. <http://dx.doi.org/10.1080/07370008.2011.636495>.
- Boseley, S. (2014, August 2). *British Medical Journal acted correctly in controversy over statins*. The Guardian. Retrieved from <http://www.theguardian.com/society/2014/aug/02/british-medical-journal-correct-articles-mistaken-fear-statins>.
- Bråten, I. (2008). Personal epistemology, understanding of multiple texts, and learning within internet technologies. In M. S. Khine (Ed.), *Knowing, knowledge and beliefs* (pp. 351–376). Dordrecht: Springer Netherlands. Retrieved from <http://www.springerlink.com/content/j664674514614405/>.
- Bråten, I., Braasch, J. L. G., Strømsø, H. I., & Ferguson, L. E. (2014). Establishing trustworthiness when students read multiple documents containing conflicting scientific evidence. *Reading Psychology*, 0(0), 1–35. <http://dx.doi.org/10.1080/02702711.2013.864362>.
- Bråten, I., & Strømsø, H. I. (2006). Epistemological beliefs, interest, and gender as predictors of Internet-based learning activities. *Computers in Human Behavior*, 22(6), 1027–1042. <http://dx.doi.org/10.1016/j.chb.2004.03.026>.
- Bråten, I., & Strømsø, H. I. (2009). Effects of task instruction and personal epistemology on the understanding of multiple texts about climate change. *Discourse Processes*, 47(1), 1–31. <http://dx.doi.org/10.1080/01638530902959646>.
- Bråten, I., Strømsø, H. I., & Salmerón, L. (2011). Trust and mistrust when students read multiple information sources about climate change. *Learning and Instruction*, 21(2), 180–192. <http://dx.doi.org/10.1016/j.learninstruc.2010.02.002>.
- Bråten, I., Strømsø, H. I., & Samuelstuen, M. S. (2005). The relationship between internet-specific epistemological beliefs and learning within internet technologies. *Journal of Educational Computing Research*, 33(2), 141–171. <http://dx.doi.org/10.2190/E763-XOLN-6NMF-CB86>.
- Bråten, I., & Weinstein, C. E. (2004). *Internet-specific epistemological questionnaire (ISEQ)*. Austin, TX: Department of Educational Psychology, University of Texas at Austin.
- British Educational Research Association. (2011). *Ethical Guidelines for educational research*. British Psychological Society. Retrieved from <https://www.bera.ac.uk/researchers-resources/resources-for-researchers>.
- British Psychological Society. (2014). *Code of human research Ethics*. British Psychological Society. Retrieved from http://www.bps.org.uk/system/files/Public%20files/code_of_human_research_ethics_dec_2014_inf180_web.pdf.
- Bromme, R., Pieschl, S., & Stahl, E. (2009). Epistemological beliefs are standards for adaptive learning: A functional theory about epistemological beliefs and metacognition. *Metacognition and Learning*, 5(1), 7–26. <http://dx.doi.org/10.1007/s11409-009-9053-5>.
- Cho, Y. H., Lee, J., & Jonassen, D. H. (2011). The role of tasks and epistemological beliefs in online peer questioning. *Computers & Education*, 56(1), 112–126. <http://dx.doi.org/10.1016/j.compedu.2010.08.014>.
- Costello, A. B., & Osborne, J. W. (2005). Getting the most from your analysis. *Practical Assessment Research & Evaluation*, 10(7). Retrieved from <http://pareonline.net/pdf/v10n7.pdf>.
- Ellis, D., Wilson, T. D., Ford, N., Foster, A., Lam, H. M., Burton, R., et al. (2002). Information seeking and mediated searching. Part 5. User–intermediary interaction. *Journal of the American Society for Information Science and Technology*, 53(11), 883–893. <http://dx.doi.org/10.1002/asi.10133>.
- FDA. (2007, August 9). *FDA warns consumers to avoid red yeast rice products promoted on internet as treatments for high cholesterol* [WebContent]. Retrieved from <http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/2007/ucm108962.htm>.
- Ferguson, L. E. (2014). Epistemic beliefs and their relation to multiple-text comprehension: A Norwegian program of research. *Scandinavian Journal of Educational Research*, 0(0), 1–22. <http://dx.doi.org/10.1080/00313831.2014.971863>.
- Foster, J. (2009). Understanding interaction in information seeking and use as a discourse: A dialogic approach. *Journal of Documentation*, 65(1), 83–105. <http://dx.doi.org/10.1108/00220410910926130>.
- Gallagher, J. (2014, July 18). *Statins: Millions more to get drugs in controversial plans*. BBC News. Retrieved from <http://www.bbc.co.uk/news/health-28352290>.
- Gil, L., Bråten, I., Vidal-Abarca, E., & Strømsø, H. I. (2010). Understanding and integrating multiple science Texts: Summary tasks are sometimes better than argument tasks. *Reading Psychology*, 31(1), 30–68. <http://dx.doi.org/10.1080/02702710902733600>.
- Gordon, R. Y. (2010). Marked variability of monacolin levels in commercial red yeast rice Products: Buyer beware! *Archives of Internal Medicine*, 170(19), 1722–1727. <http://dx.doi.org/10.1001/archinternmed.2010.382>.
- Hagen, A. M., Braasch, J. L. G., & Bråten, I. (2012). Relationships between spontaneous note-taking, self-reported strategies and comprehension when reading multiple texts in different task conditions. *Journal of Research in Reading*. <http://dx.doi.org/10.1111/j.1467-9817.2012.01536.x>.
- Hansen, P., Shah, C., & Klas, C.-P. (2015). *Collaborative information Seeking: Best practices, new domains, new thoughts*. Springer. Retrieved from <http://link.springer.com/book/10.1007/978-3-319-18988-8?no-access=true>.
- Harding, A. (2008, July 9). *Contamination common in red yeast rice products*. Reuters. Retrieved from <http://www.reuters.com/article/2008/07/09/us-contamination-common-idUSCOL97022820080709>.
- Hargittai, E., Fullerton, L., Menchen-Trevino, E., & Thomas, K. Y. (2010). Trust Online: Young adults' evaluation of web content. *International Journal of Communication*, 4(0), 27. Retrieved from <http://ijoc.org/index.php/ijoc/article/view/636>.
- Heilman, J. M., Kemmann, E., Bonert, M., Chatterjee, A., Ragar, B., Beards, G. M., et al. (2011). Wikipedia: A key tool for global public health promotion. *Journal of Medical Internet Research*, 13. Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/pmc3221335/>.
- Hofer, B. K. (2004). Epistemological understanding as a metacognitive Process: Thinking aloud during online searching. *Educational Psychologist*, 39(1), 43–55. http://dx.doi.org/10.1207/s15326985ep3901_5.
- Horgan, Áine, & Sweeney, J. (2012). University students' online habits and their use of the internet for health information. *CIN: Computers, Informatics, Nursing*, 30(8), 402–408. <http://dx.doi.org/10.1097/NXN.0b013e3182510703>.
- Hsu, C.-Y., Tsai, M.-J., Hou, H.-T., & Tsai, C.-C. (2013). Epistemic beliefs, online search strategies, and behavioral patterns while exploring socioscientific issues. *Journal of Science Education and Technology*, 1–10. <http://dx.doi.org/10.1007/s10956-013-9477-1>.
- Hwang, G.-J., Tsai, P.-S., Tsai, C.-C., & Tseng, J. C. R. (2008). A novel approach for assisting teachers in analyzing student web-searching behaviors. *Computers & Education*, 51(2), 926–938. <http://dx.doi.org/10.1016/j.compedu.2007.09.011>.
- Kammerer, Y., Amann, D. G., & Gerjets, P. (2015). When adults without university education search the Internet for health information: The roles of Internet-specific epistemic beliefs and a source evaluation intervention. *Computers in Human Behavior*, 48, 297–309. Retrieved from <http://www.sciencedirect.com/science/article/pii/S074756321500059X>.
- Kammerer, Y., Bråten, I., Gerjets, P., & Strømsø, H. I. (2013). The role of Internet-specific epistemic beliefs in laypersons' source evaluations and decisions during Web search on a medical issue. *Computers in Human Behavior*, 29(3), 1193–1203. <http://dx.doi.org/10.1016/j.chb.2012.10.012>.
- Knight, S. (2016). *Developing learning analytics for epistemic commitments in a collaborative information seeking environment* (PhD). Milton Keynes, UK: Open University. Retrieved from <http://oro.open.ac.uk/46143/>.
- Knight, S., & Mercer, N. (2015). The role of exploratory talk in classroom search engine tasks. *Technology, Pedagogy and Education*, 24(3), 303–319. <http://dx.doi.org/10.1080/1475939X.2014.931884>.
- Knight, S., & Mercer, N. (2017). The role of collaborative, epistemic discourse in classroom information seeking tasks. *Technology, Pedagogy and Education*, 26(1), 33–50. <http://dx.doi.org/10.1080/1475939X.2016.1159978>.
- Kuiper, E., Volman, M., & Terwel, J. (2009). Developing Web literacy in collaborative inquiry activities. *Computers & Education*, 52(3), 668–680. <http://dx.doi.org/10.1016/j.compedu.2008.11.010>.
- Lazonder, A. W. (2005). Do two heads search better than one? Effects of student collaboration on web search behaviour and search outcomes. *British Journal of Educational Technology*, 36(3), 465–475. <http://dx.doi.org/10.1111/j.1467-8535.2005.00478.x>.
- Lin, C.-C., & Tsai, C.-C. (2007). A navigation flow map method of representing students' searching behaviors and strategies on the web, with relation to searching outcomes. *CyberPsychology & Behavior*, 10(5), 689–695. <http://dx.doi.org/10.1089/cpb.2007.9969>.
- Livingstone, S., Bober, M., & Helsper, E. (2005). *Internet literacy among children and young people: Findings from the UK children go online project*. London: LSE Research Online. Retrieved from <http://eprints.lse.ac.uk/397/1/UKCGOonlineLiteracy.pdf>.
- Lu, Z., Kou, W., Du, B., Wu, Y., Zhao, S., Brusco, O. A., et al. (2008). Effect of Xuezhikang, an extract from red yeast Chinese rice, on coronary events in a Chinese population with previous myocardial infarction. *The American Journal of Cardiology*, 101(12), 1689–1693. <http://dx.doi.org/10.1016/j.amjcard.2008.02.056>.
- Macrae, F. (2008, June 10). *Quack medicine: Peking duck is "better for your heart than statins"*. Mail Online. Retrieved from <http://www.dailymail.co.uk/health/article-1025277/Quack-medicine-Peking-duck-better-heart-statins.html>.
- Mason, L., Ariasi, N., & Boldrin, A. (2011). Epistemic beliefs in action: Spontaneous reflections about knowledge and knowing during online information searching and their influence on learning. *Learning and Instruction*, 21(1), 137–151. <http://dx.doi.org/10.1016/j.learninstruc.2010.01.001>.
- Mason, L., Boldrin, A., & Ariasi, N. (2010a). Epistemic metacognition in context: Evaluating and learning online information. *Metacognition and Learning*, 5(1), 67–90. <http://dx.doi.org/10.1007/s11409-009-9048-2>.
- Mason, L., Boldrin, A., & Ariasi, N. (2010b). Searching the web to learn about a controversial topic: Are students epistemically active? *Instructional Science*, 38(6), 607–633. <http://dx.doi.org/10.1007/s11251-008-9089-y>.
- Mokhtari, H. (2014). A quantitative survey on the influence of students' epistemic beliefs on their general information seeking behavior. *The Journal of Academic Librarianship*, 40(3–4), 259–263. <http://dx.doi.org/10.1016/j.acalib.2014.04.001>.
- Mozilla. (2014). *Firefox*. Retrieved from <https://www.mozilla.org/en-US/firefox/new/>.
- NHS Choices. (2008, June 9). *Chinese red yeast rice - health news - NHS Choices*. Retrieved from <http://www.nhs.uk/news/2008/06June/Pages/Redyeastriceandheartdisease.aspx>.

- OECD. (2013). *PISA 2015: Draft reading literacy framework*. OECD Publishing. Retrieved from <http://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Reading%20Framework%20.pdf>.
- OECD, & Statistics Canada. (2010). *Literacy in the information age - final report of the international adult literacy survey*. OECD. Retrieved from <http://www.oecd.org/edu/skills-beyond-school/41529765.pdf>.
- Ridker, P. M., & Cook, N. R. (2013). Statins: New American guidelines for prevention of cardiovascular disease. *The Lancet*, 382(9907), 1762–1765. [http://dx.doi.org/10.1016/S0140-6736\(13\)62388-0](http://dx.doi.org/10.1016/S0140-6736(13)62388-0).
- Rouet, J.-F., & Britt, M. A. (2011). Relevance processes in multiple document comprehension. In M. T. McCrudden, J. P. Magliano, & G. Schraw (Eds.), *Text relevance and learning from text* (pp. 19–52). Information Age Publishing (IAP). Retrieved from http://www.niu.edu/britt/recent_papers/pdfs/RouetBritt_chapter_for_McCrudden.pdf.
- Salmerón, L., & Kammerer, Y. (2012). *Selecting Pages from Google to Learn about a Controversial Topic: The Role of Epistemic Beliefs. Staging knowledge and experience: How to take advantage of representational technologies in education and training?* (Vol. 181). Retrieved from http://tefca.unige.ch/~mireille/graphicacy/EARLI_SIG2_Proceedings_2012.pdf#page=181.
- Schmidt, C. W. (2012). Trending now: Using social media to predict and track disease outbreaks. *Environmental Health Perspectives*, 120(1), a30–a33. <http://dx.doi.org/10.1289/ehp.120-a30>.
- Schmidt, H. G., Molen, H. T. V. D., Winkel, W. W. R. T., & Wijnen, W. H. F. W. (2009). Constructivist, problem-based learning does work: A meta-analysis of curricular comparisons involving a single medical school. *Educational Psychologist*, 44(4), 227–249. <http://dx.doi.org/10.1080/00461520903213592>.
- Schraw, G. (2000). *Assessing metacognition: Implications of the Buros symposium. Issues in the measurement of metacognition*.
- Schraw, G., & Impara, J. C. (2000). *Issues in the measurement of metacognition*. Buros Institute of Mental Measurements and Department of Educational Psychology, University of Nebraska-Lincoln.
- Shah, C. (2012). *Information Retrieval: Collaborative information seeking: The art and science of making the whole greater than the sum of all*. Springer.
- Shah, C. (2014). *Coagmento*. Retrieved from <http://coagmento.org/>.
- Shah, C., & González-Ibáñez, R. (2011). Evaluating the synergic effect of collaboration in information seeking. In *Proceedings of the 34th international ACM SIGIR conference on research and development in information retrieval* (pp. 913–922). New York, NY, USA: ACM. <http://dx.doi.org/10.1145/2009916.2010038>.
- Shah, C., Hendahewa, C., & González-Ibáñez, R. (2015). Rain or Shine? Forecasting search process performance in exploratory search tasks. *Journal of the Association for Information Science and Technology*. <http://dx.doi.org/10.1002/asi.23484>.
- Strømshø, H. I., & Bråten, I. (2010). The role of personal epistemology in the self-regulation of internet-based learning. *Metacognition and Learning*, 5(1), 91–111. <http://dx.doi.org/10.1007/s11409-009-9043-7>.
- Strømshø, H. I., Bråten, I., & Britt, M. A. (2011). Do students' beliefs about knowledge and knowing predict their judgement of texts' trustworthiness? *Educational Psychology*, 31(2), 177–206. <http://dx.doi.org/10.1080/01443410.2010.538039>.
- Tempelaar, D. T., Niculescu, A., Rienties, B., Gijssels, W. H., & Giesbers, B. (2012). How achievement emotions impact students' decisions for online learning, and what precedes those emotions. *The Internet and Higher Education*, 15(3), 161–169. <http://dx.doi.org/10.1016/j.iheduc.2011.10.003>.
- Tseng, J. C. R., Hwang, G.-J., Tsai, P.-S., & Tsai, C.-C. (2009). Meta-analyzer: A web-based learning environment for analyzing student information searching behaviors. *Computing, Information and Control*, 5(3), 567–579. Retrieved from <http://www.ijicic.org/icic07-is03-12-1.pdf>.
- Van Strien, J., Brand-Gruwel, S., & Boshuizen, E. (2012). *Do prior attitudes influence epistemic cognition while reading conflicting information?*. Retrieved from <http://dSPACE.ou.nl/handle/1820/4390>.
- Walraven, A., Brand-Gruwel, S., & Boshuizen, H. (2008). Information-problem solving: A review of problems students encounter and instructional solutions. *Computers in Human Behavior*, 24(3), 623–648. <http://dx.doi.org/10.1016/j.chb.2007.01.030>.
- Wildemuth, B. M., & Freund, L. (2012). Assigning search tasks designed to elicit exploratory search behaviors. In *Proceedings of the symposium on human-computer interaction and information retrieval* (pp. 4:1–4:10). New York, NY, USA: ACM. <http://dx.doi.org/10.1145/2391224.2391228>.
- Williams, P., & Rowlands, I. (2007, October 18). *Information behaviour of the researcher of the future*. JISC. Retrieved from <http://www.ucl.ac.uk/infostudies/research/ciber/downloads/GC%20Work%20Package%20II.pdf>.
- Wu, C.-H., Hwang, G.-J., & Kuo, F.-R. (2014). Collab-Analyzer: An environment for conducting web-based collaborative learning activities and analyzing students' information-searching behaviors. *Australasian Journal of Educational Technology*, 30(3). Retrieved from <http://ascilite.org.au/ajet/submission/index.php/AJET/article/view/998>.
- Yue, Z., Jiang, J., Han, S., & He, D. (2012). Where do the query terms come from?: an analysis of query reformulation in collaborative web search. In *Proceedings of the 21st ACM international conference on Information and knowledge management* (pp. 2595–2598). Retrieved from <http://dl.acm.org/citation.cfm?id=2398700>.